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Interactive comment on "FTS measurements of column CO_2 at Sodankylä" *by* R. Kivi and P. Heikkinen

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We thank the Referee for the comments, which are very helpful to improve the paper. Below we provide answers to all comments and questions by the Referee.

Referee: "Title: Although the site may be well known to the TCCON community the title should finish with: "..., Finland". Abstract: Similarly the abstract should cite the latitude and longitude (rounded to the nearest degree) and explain the significance of the site location for the TCCON monitoring".

Authors: We have revised the abstract according to these suggestions.

Referee: "Section 1 Introduction: The authors state that "compared to the surface in situ measurements the XCO2 is much less affected by vertical transport" (lines 2-3

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Discussion paper

p2). Apparently the authors think this is an advantage, but the significance needs to be explained. Instantaneous surface in situ CO2 measurements are more relevant for modelling gross primary productivity since they more accurately represent the atmospheric composition encountered by plants. The authors should spell out why their XCO2 provide an advantage over these in situ values. It would also be helpful to explain how the XCO2 measurements are dominated by lower tropospheric components given the atmospheric density/pressure profile. Additionally, they should cite studies that directly compare ground based FTS XCO2 against satellite FTS XCO2."

Authors: We have modified the text in the revised version.

Referee: "Section 4 XCO2 time series and the annual cycle: 1) The authors should discuss the actual measurements shown in Fig 6 before the mean seasonal cycle shown in Fig 5. Hence swop the fig order and move the paragraph on lines 9-14 on p7 to the start of section 4."

Authors: This is a very valuable suggestion. We have changed the order of the Figures in the revised version of the manuscript. In addition we have also revised the Section 4.

Referee: "Fig 6 (to become Fig 5) shows how variable the scatter and numbers of measurements are from month to month. The figure would be improved by plotting in a new panel the mean monthly XCO2 (i.e. for each month of each year) plus their uncertainties (as 95% confidence intervals)."

Authors: We have added a new Figure, which provides monthly mean values and also the standard deviations for each month.

Referee: "In obtaining the mean monthly XCO2 over 6 years from the data the authors must have subtracted the linear interannual trend. The authors have not explained how estimated the trend – did they use a regression of each monthly mean allowing for the uncertainty in each month (i.e. allowing for dependent variable errors) or did they

regress using the individual measurement values shown in Fig 6? We are also not told what "+/-0.3 ppm per year" represents (+/-standard deviation or +/-standard error or +/-95% CI)."

Authors: The trend was calculated using monthly means. Detrended monthly values were then used to calculate the seasonal cycle. "+/-0.2 ppm per year" represents +/-standard error of the linear fit.

Referee: "The mean monthly XCO2 over 6 years in Fig 5 is shown with standard deviations as though error bars/uncertainties. This is incorrect as it is the standard error of the mean (or better the 95% CI) and NOT the standard deviation that indicates the minimum uncertainty in the mean values. The highly variable number of observations per month would be reflected by the SEM or 95% CI ranges. In fact the uncertainty in the mean monthly values over 6 years should also allow for the effect of the uncertainty in the linear trend.

Authors: We find that plotting the uncertainty may not be very straightforward, because the standard error of mean is very small compared to the annual cycle. Within one monthly mean value there are in average 1300 measurements. Standard deviation of the measurements is in average 0.9 ppm. Therefore the standard error is typically of the order of 0.025 ppm. It means that the size of the marker is greater than the uncertainty. We have therefore used standard deviation to describe the observed variability. The standard deviations in summer are large due to the relatively high interannual variability.

Referee: "We are told (p 6 line 23-24) that minimum XCO2 occurs in August due to CO2 uptake by plants. This is far too vague. They should cite publications describing variations in gross primary productivity and heterotrophic (soil) respiration since net ecosystem exchange (NEE) is relevant here. This issue returns on lines 7 and 8 of p7 where ECMWF modelling of decreased XCO2 (by modelling NEE via phenology etc) is said to precede the Soldankyla FTS XCO2 by a whole month. The significance of

this mis-match cannot be judged without knowing how the timing of observed Finnish NEE varies compares to the variation in Soldankyla FTS XCO2 (which must be later – but by how much?). In fact it would be useful to know how the new XCO2 values vary on average (over 6 years) over time scales much shorter than a month (e.g. weekly)."

Authors: we have revised the text of Section 4.

All technical corrections suggested by the Referee have been made. p2 line2 "HDF" > "HDO".

p2 line2: Put "in situ" into italics here and later to be consistent with p1 line 24.

p3 line9: "is working" > "has worked".

p3 line 27-28: "on monthly" > "on a monthly".

p3 line 30: "phase orientation" > "phase orientation errors" (similarly correct caption of Fig 2 and Y axis in lower panel Fig 2 to "phase orientation errors").

p3 line 32: Move sentence starting "Modulation efficiency..." in front of sentence on line 31 p 3 starting "The spread of values...".

p4 End of section 2: Explain why amplitude modulation for 2012 is so different to 2013 & 2014. Explain why July 2012 phase orientation error so different to other dates.

Done

p4 lines 22-23: "This is increasing" > "This increases".

p4 lines 26-27: "which is making" > "which makes".

p4 line 30: "In ideal" > "In an ideal".

Fig 2: Add arrow and note for August 2013 "Positioning board replaced".

Done

38, 2016.